

# Processing Digital Imagery To Enhance Perceptions of Realism

Perceptible color and detail are superior to those of other image-enhancement methods.

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Multi-scale retinex with color restoration (MSRCR) is a method of processing digital image data based on Edwin Land's retinex (retina + cortex) theory of human color vision. An outgrowth of basic scientific research and its application to NASA's remote-sensing mission, MSRCR is embodied in a general-purpose algorithm that greatly improves the perception of visual realism and the quantity and quality of perceived information in a digitized image. In addition, the MSRCR algorithm includes provisions for automatic corrections to accelerate and facilitate what could otherwise be a tedious image-editing process. The MSRCR algorithm has been, and is expected to continue to be, the basis for development of commercial image-enhancement software designed to extend and refine its capabilities for diverse applications.

Initially, a color image is divided spatially into pixels and, within each pixel, intensity levels are digitized in  $S$  spectral bands. Hence, the initial image data are in the form  $I_i(x,y)$ , where  $x$  and  $y$  are Cartesian pixel coordinates and the subscript  $i$  denotes the  $i$ th spectral band. The MSRCR algorithm begins with the computation of an adjusted value of each  $I_i(x,y)$  in accordance with

$$I_i(x,y)_{\text{adjusted}} = \sum_{n=1}^N w_n \{ \log I_i(x,y) - \log [I_i(x,y) * F_n(x,y)] \}$$

where  $w_n$  is the  $n$ th of  $N$  weighting factors,  $F_n(x,y)$  is the  $n$ th of  $N$  surround functions, and "\*" denotes the convolution operator. Each surround function is uniquely scaled to improve an aspect of the digital image; e.g., dynamic range compression, color constancy, or lightness rendition. The adjusted intensity value for each spectral band at each position is filtered with a common function and then presented to a display device. In the case of a color image, a color-restoration step (essentially, an additional filtering step) is included to make

the image give rise to a human perception of color that closely matches the color perception of a human viewing the original scene depicted in the image.

In the perception of a human viewer, a digital image enhanced by the MSRCR algorithm resembles the original scene, under all kinds and levels of lighting, more closely than does a digital image of the same scene enhanced by any prior known image-data-processing algorithm.

sure that colors in shadowed or brightly illuminated areas are not lost or severely attenuated.

Commercial software, Photoflair for Windows, based on the MSRCR algorithm is now available for use by amateur photographers to optimize brightness and contrast and to enhance detail, and overall sharpness and quality of images. There are numerous other potential applications in medical imaging,



Details in Shadows are more readily perceptible after processing by software based on the MSRCR algorithm.

Other attributes that make the MSRCR algorithm superior to other such algorithms include the following:

- Because all of the desired image-enhancement and -correction functions are performed in a single step, it is much easier for consumers to use software based on the MSRCR algorithm to obtain high-quality digital images. For the same reason, significantly less processing time is needed. No manual manipulations of data are required. However, the user is given the option, at the end, to perform any desired additional manipulations of data.
- The MSRCR algorithm is able to ensure that details are not lost when illumination conditions are not optimal (i.e., in shadowed or brightly illuminated zones of an image, as shown in the figure). The algorithm also en-

forensic imaging, and editing of motion pictures.

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In accordance with Public Law 96-517, the contractor has elected to retain title to this invention. Inquiries concerning rights for its commercial use should be addressed to

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